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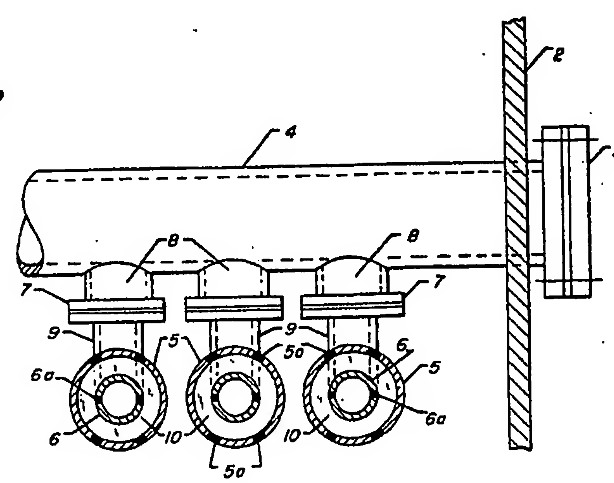
(54) Fluid distributor for fixed-bed catalytic reaction zones

(57) A distributor device for effecting uniform distribution of a fluid stream (which may be in vaporous phase, liquid phase or mixed phase) to a fixed-bed of catalyst particles contained in a reaction chamber 2 has a fluid inlet conduit 4 and a plurality of spaced-apart parallel conduits, each of which consists of two concentric and coaxial perforated pipes 5 and 6, these parallel conduits being disposed in a plane perpendicular to the vertical plane containing the axis of the inlet conduit. Fluid for distribution is introduced from the inlet conduit 4 into the inner conduit 6, while fluid from that portion of catalyst above the device flows into the outer conduit 5 and is distributed therefrom into the catalyst particles below.

The distributor is of use in the quenching of hydrocarbon conversion reactions.

Fig 2



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig 1

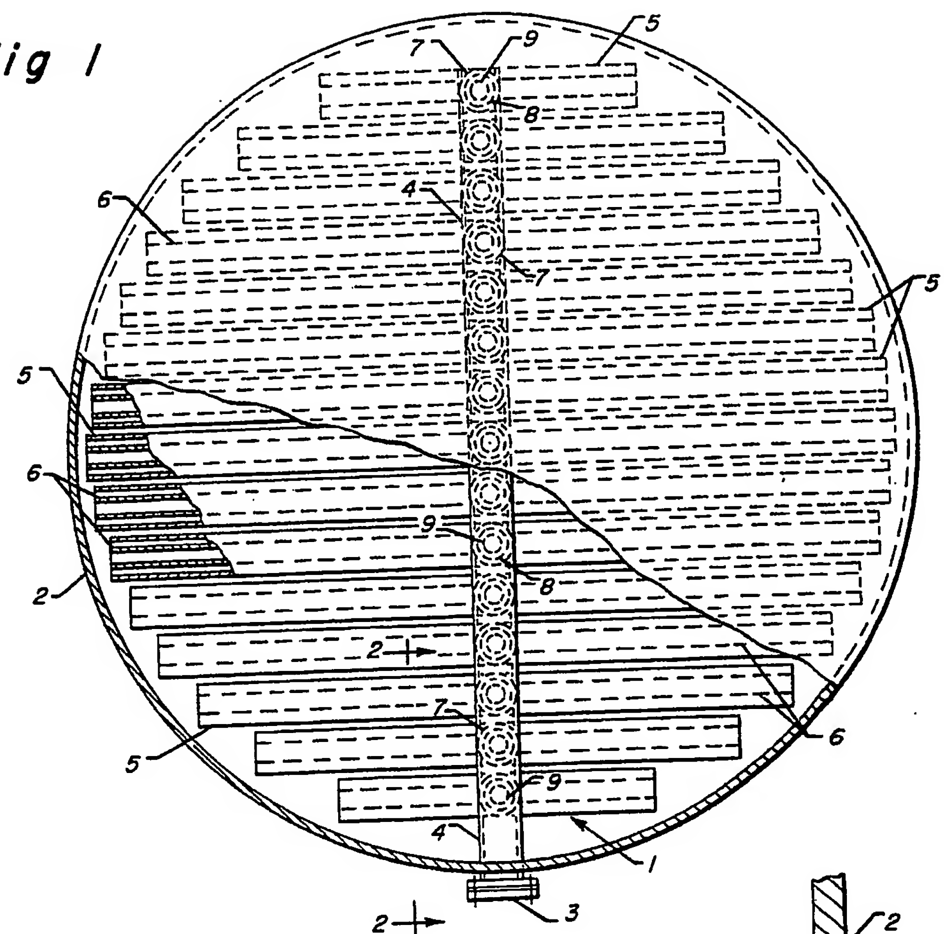


Fig 2

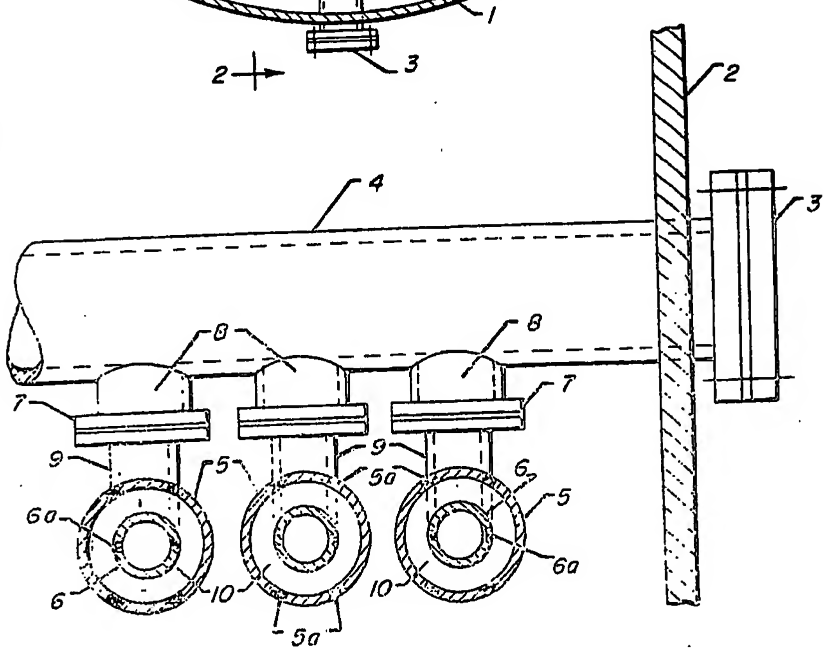


Fig 3

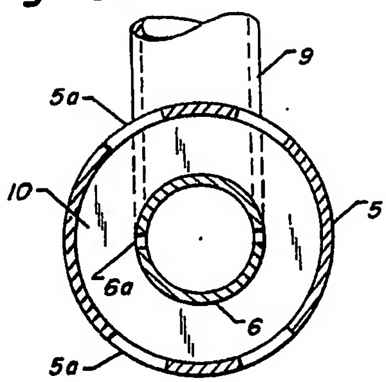


Fig 4

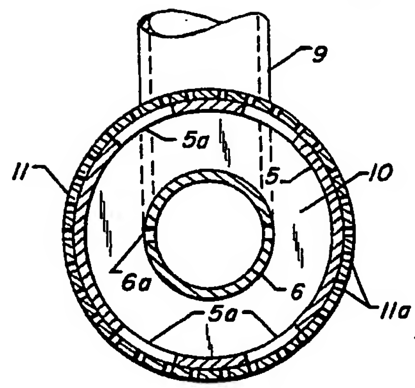


Fig 5

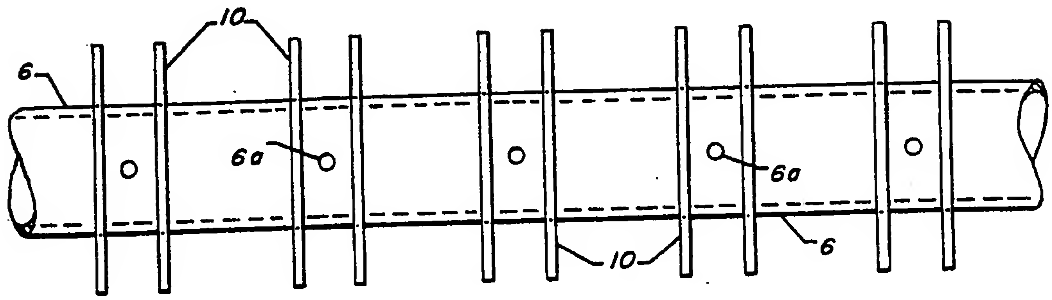
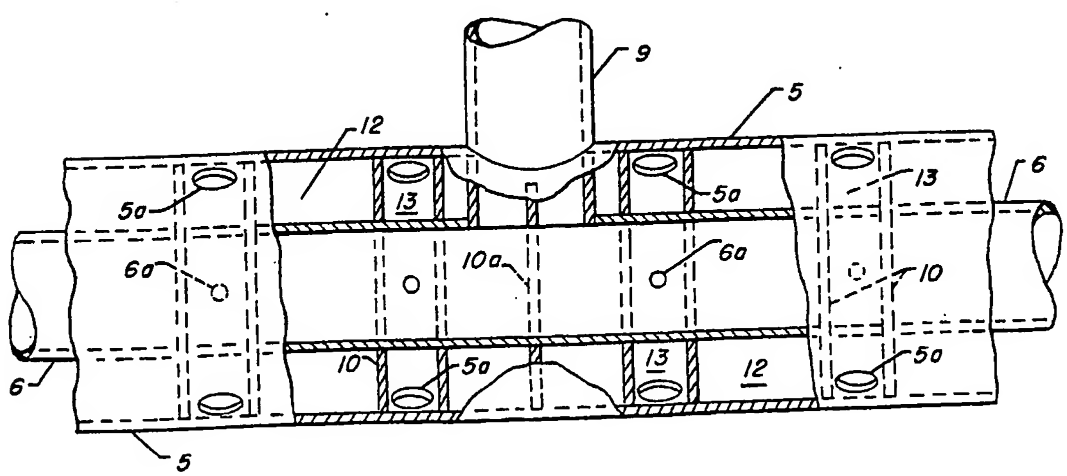


Fig 6



SPECIFICATION

Fluid distributor for fixed-bed catalytic reaction zones

The present invention relates to fluid distributors for use in fixed-bed catalytic reaction zones, particularly those for utilization in processes widely practiced within the petroleum and petrochemical industries, to distribute fluid within the catalyst bed. The fluid distribution device may be used for the distribution through the catalyst bed of a heating medium in a pricipally endothermic process, or a quench (cooling) stream in an exothermic process. The distributor, which may be used in connection with processes effected in vapor phase, liquid phase or mixed-phase serves to introduce into the reaction zone a liquid, vapor, or mixed vapor/liquid stream. In the interests of clarity and brevity, but without the intent to so limit our invention, further description and discussion will be directed toward the introduction of a vaporous quench stream in an exothermic process which is conducted in mixed-phase.

Mixed-phase hydrocarbon conversion reactions are generally effected in exothermic processes where the fresh feed charge stock predominates in hydrocarbons boiling above the gasoline, or naphtha boiling range—i.e. above a temperature of 204°C. at atmospheric pressure. Often, the mixed-phase reactant stream will consist of liquid hydrocarbon constituents and a hydrogen-rich vaporous phase. Charge stocks include kerosene fractions, light and heavy gas oils (both atmospheric and vacuum) and asphaltenic black oils containing constituents boiling above about 566°C. Obviously, our invention does not rely for viability upon a particular hydrocarbonaceous charge stock, nor upon the particular reaction, or reactions being effected. The latter include hydrocracking, hydrogenation, desulfurization and/or denitrogenation, hydrotreating and various combinations thereof, all of which are hydrogen-consuming and, therefore, principally exothermic in nature. Although the distributor herein described is capable of uniformly distributing the reactant stream as the same is initially introduced into the catalytic reaction vessel, it is primarily intended for the inner-catalyst introduction of a fluid quench, or cooling stream.

Paramount to successful hydrogen-consuming, mixed-phase processing, is the uniform distribution of the reactant stream throughout the bed of catalyst particles. This is especially true at those loci within the catalyst bed at which the quench stream is introduced. Tantamount to hydrogen-consuming reactions is the continuous contact of the hydrocarbon phase with hydrogen throughout the bed of catalyst particles. At the points of quench stream introduction, whether liquid or vaporous, it is also important to distribute the quench stream uniformly into the reactant stream to insure equally important uniform quenching of the reactant stream, or uniform heat trasnfer to the quench stream. The distributing device encompassed by our inventive concept readily achieves these necessary results.

The present invention seeks to provide a device for distributing a fluid uniformly to a bed of catalyst particles, which device can be used to distribute an external fluid stream uniformly into a reactant stream traversing a fixed-bed of catalyst particles.

It would also be desirable, in an exothermic reaction system, to provide means whereby uniform heat transfer from the reactant stream to the fluid quench stream introduced intermediate the bed of catalyst particles is afforded, and to provide an intimate thorough mixture of an external fluid stream with the internal reactant stream.

According to the invention there is provided a fluid distribution device for use in a catalytic reaction chamber containing a fixed bed of catalyst to distribute fluid within the catalyst bed, which device comprises, in cooperative relationship: (a) a fluid inlet conduit; (b) a first plurality of spaced-apart, perforated fluid distribution conduits in open communication with the fluid inlet conduit and disposed in a plane perpendicular to the vertical plane containing the axis of the fluid inlet conduit; and, (c) a second plurality of perforated fluid distribution conduits, having a nominal diameter greater than the first distribution conduits, one each of which is coaxially and concentrically disposed around each of the first distribution conduits.

When present in a catalytic reaction chamber the fluid distribution device preferably occupies from 60% to 90% of the horizontal cross-sectional area of the reaction chamber.

Preferably, annular-form, spaced-apart stabilizing discs, or washers, having a major diameter substantially the same as the internal diameter of the second (i.e. larger) distribution conduits, surround the first (i.e. smaller) distribution conduits and are disposed substantially perpendicular to the longitudinal axis thereof.

It must be recognized and acknowledged that the prior art contains a variety of fluid distribution devices to introduce (1) a mixed-phase, or single phase reactant stream into a catalytic reaction zone, (2) a vaporous and/or liquid quench, or heating stream at one or more intermediate loci within a fixed-bed of catalyst particles and, (3) the mixed-phase effluent from an upper catalyst bed into the next succeeding lower catalyst bed. Many of the prior art fluid distributing devices utilize a horizontal plate through which a plurality of downcomers extend. This technique is illustrated by United States Patent Nos. 3,146,189; 3,378,349; and 3,524,731.

Distributor devices similar to the present

invention are found in the prior art as shown by United States Patent No. 2,632,692. Here the distributor device is situated in a catalyst-free area between two horizontal, perforated plates. In this instance, the device consists of a pair of concentric, perforated toroidal rings connected to each other by a cross conduit which, in turn, communicates with the inlet conduit which supplies the quenching fluid. It will be noted that each toroidal ring is unitary in and of itself; that is, the device does not contemplate a second such ring totally within the confines of the first.

The distributor device shown in United States Patent No. 2,860,955 more closely resembles the fluid distribution device according to the invention. Here, the inlet conduit tangentially introduces the mixed-phase fluid stream into a separation zone. Liquid components flow downwardly into a horizontal header which in turn feeds a plurality of perpendicularly-disposed, perforated distribution conduits. Again, each of the distribution conduits is unitary in construction.

United States Patent No. 3,208,833 offers a fluid distribution device which resembles that of 2,632,692 discussed above. Here, however, the device, consisting of a multiplicity of concentric, perforated rings, rectangular in cross-section, is capable of being back-flushed for removal of a retained fluid. These ring sections are interconnected through a plurality of short hollow tubular members which distribute the feed fluid through all of the spaced-apart distributing rings. It is again noted that all of the distributing rings are of unitary construction.

As hereinbefore set forth, the fluid distribution device of the present invention is adaptable for utilization in those fixed-bed catalytic systems in which the reactions are effected in vapor phase, liquid phase or in mixed phase. Additionally, the device may be utilized to distribute the reactant stream initially into the reaction chamber, or to distribute a heating medium or quenching stream at one or more intermediate loci within the bed of catalyst particles. The following discussion will be directed toward a mixed-phase exothermic reaction chamber wherein the exothermicity of reaction is controlled, or tempered through the use of a vaporous hydrogen quench. Distribution of a quench stream to a fixed-bed of catalyst particles, in accordance with the present invention, is founded upon recognition of the fact that provisions have not heretofore been afforded which will alleviate the difficulties and problems associated with (1) uniform and thorough mixing of the quench stream with the flowing reactant stream and, (2) uniform transfer of heat to the quench stream throughout the cross-sectional area of the catalyst particles at the various quench introduction loci.

In further describing our invention, both ranges of and specific dimension will be given. It is understood that these are presented solely for illustration purposes, and not with the intent to limit the present invention, the scope of which is defined by the claims. The precise design of a fluid distribution device is dependent upon many considerations pertinent to the particular process with which the device is to be integrated. These include at least the following: the physical and chemical characteristics of the charge stock, or reactant stream; the character of the reactions being effected, and the intended product quality; the charge stock feed rate; the dimensions of the catalytic reaction chamber; the quantity of the catalyst disposed therein; and, the degree of exothermic reaction experienced.

In accordance with the present invention, the quench stream is introduced into the reaction chamber through an inlet conduit which is in open communication with a plurality of perforated distribution conduits, each of which is encased within an outer perforated conduit having a larger nominal internal diameter. Each quench distribution conduit consists of a pair of coaxially and concentrically disposed perforated pipes. The quench inlet conduit is in direct communication only with the smaller, or inner distribution conduit, and is disposed, or aligned with the diameter of the reaction chamber. Double-pipe distribution conduits are spaced apart, and disposed in a plane which is perpendicular to the vertical plane containing the central axis of the quench inlet conduit. The quench distribution conduits may take the form of toroidal rings, similar to those shown in the art, or of individual conduits closed at both ends. In the latter configuration, the central axes of the distribution conduits will be parallel chords of the reaction chamber.

In the more conventional quench distribution devices, difficulties have arisen as a result of heat-distortion of the device or uneven catalyst loading and distribution. This results in discharge from the conduits into various portions of the catalyst bed which are functioning at variant pressures, and thus leads to non-uniform heat distribution. Furthermore, distortion of the device permits flow from high pressure areas to lower pressure areas, again contributing to poor heat distribution, as well as non-uniform mixing throughout the bed of catalyst particles. The co-tubular, double-pipe distribution conduits of the present device readily afford the solutions to these problems. Distortion under high-severity operating conditions is virtually non-existent by virtue of the provision of the larger, outer conduit.

Distortion of the device with resulting non-uniform flow may be additionally eliminated by providing annular-form, spaced-apart stabilizing discs, or washers, around the inner pipe, which washers have a major diameter substantially the same as the internal diameter of

the outer, larger conduit, and which are disposed substantially perpendicular to the longitudinal axis thereof. Perforations in the inner and outer conduits are contained within individual internal chambers formed between a pair of stabilizing discs. Thus, the quench fluid discharging from a given perforation in the inner pipe can only be admitted into the catalyst through those perforations in the outer conduit which are between the same pair of stabilizing discs. Also provided thereby are annular stagnant areas between perforations which tend to impede the transfer of heat to the quench fluid. In other words, the quench fluid is not heated as it traverses the inner distribution conduit towards the extremities thereof.

Fluid distribution devices are usually designed for a pressure drop of 0.3 to 1 atm through the perforations in the smaller, inner conduit which usually have a diameter in the range of from 0.8 to 4 mm. The perforations in the inner conduit are desirably disposed at an angle of 90° with respect to the vertical axis, and generally two such apertures are confined within each individual internal chamber formed by a pair of the stabilizing washers. The perforations in the larger, outer distribution conduit usually have a nominal diameter of from 16 to 22 mm and are preferably chamfered inwardly (toward the center of the conduit). These are usually disposed at an angle of 30° with respect to the vertical axis, and generally from two to four are confined within each individual internal chamber. Thus, the smaller apertures are positioned such that they discharge from the inner conduit onto an imperforate inner surface of the outer conduit. The entire fluid distribution device usually occupies from 60% to 90% of the horizontal cross-sectional area of the bed of catalyst particles. The ratio of the diameter of the outer conduit to that of the inner conduit is suitably in the range from 2:1 to 4:1.

In passing the quench vapors at high velocity into the catalyst bed, precautions are required to prevent excessive attrition of the catalyst particles. With respect to the present fluid distribution device, the velocity of the vapors emanating from the apertures in the inner conduit is broken by discharging against an imperforate area of the outer conduit. By encircling the outer pipe with a perforated screen member, the velocity is again broken as the vapors discharge into the catalyst bed. Intimate, uniform mixing of the fluid quench and the internal reactant stream is accomplished by locating the outer conduit perforations 30° with respect to the top and bottom of the vertical axis. This promotes the flow of the reactant stream at the precise points of quench introduction. The design utilizes the jet effect of the quench vapors exiting through the small perforations to effectively pump the reactant stream through the individual internal chambers between the pairs of stabilizing washers. Additionally, the entire quench apparatus blocks a significant portion of the catalyst bed cross-section, such that there is a relatively high pressure drop through the catalyst bed in the spaces between individual quench conduits. This pressure drop also encourages the flow of the reactant stream through the annulus at the quench point, rather than through the catalyst.

In further describing the fluid distribution device encompassed by our inventive concept, reference will be made to the several accompanying drawings which illustrate various embodiments thereof. Since the drawings are presented for the sole purpose of providing a clear understanding of the distributor, its construction and its operation, they have not been drawn to a precise scale. As previously stated herein, the dimensions of a particular device are dependent upon a wide variety of processing considerations as well as the particular dimensions of the catalytic reaction chamber.

In one specific design, for use in a catalytic reaction chamber having an effective internal diameter of about 3.7 meters, twenty-five double-pipe distribution conduits are utilized. These are disposed on approximate 1.27 cm. centers with approximately 3.8 cm. between adjacent conduits. The inner conduit has a diameter of about 2.54 cm., and the aperture therein are 1.6 mm in diameter; the outer conduit has a diameter of 7.6 cm., and the apertures therein are 1.9 cm. in diameter. Within each of the individual internal chambers formed by a pair of stabilizing discs 2.54 cm. apart, there are two 1.6 mm. apertures and four 1.9 cm. apertures. The apertures are 7.6 cm apart, measured center to center along the axis of the conduit.

Of the accompanying drawings,

Figure 1 shows a plan view of a fluid distributing device according to the invention within a catalytic reaction chamber;

Figure 2 is a partially sectioned side elevation taken substantially along the line 2–2 of Fig. 1;

Figures 3 and 4 are enlargements of portions of Fig. 2 respectively without and with an outer perforated screen member;

Figure 5 is a side elevation of an inner (first) distribution conduit; and

Figure 6 is a side elevation, partly in section, of a pair of distribution conduits.

Referring to Fig. 1, a fluid quench stream is introduced into a fluid distributing device 1, situated in a reaction chamber 2, by way of inlet port 3 and inlet conduit 4. In this illustration of a preferred embodiment, fluid inlet conduit 4 is shown as traversing the reaction zone through the center, and as being substantially the same length as the diameter thereof. A plurality of pairs of fluid distribution conduits, each consisting of an outer

(second) pipe 5 and a smaller inner (first) pipe 6, are disposed below inlet conduit 4, and lie in a common plane which is perpendicular to the vertical plane containing the central axis of the inlet conduit. As more clearly shown in Fig. 2, fluid inlet conduit 4 communicates directly only with inner distribution conduit 6 by way of reducing couplings (or unions) 7. In the plan view of Fig. 1, the entire device occupies approximately 80% of the cross-sectional area of catalytic reaction chamber 2.

In use, as seen more clearly in Fig. 2, the fluid quench stream passes from inlet conduit 4 through short vertical pipes 8, reducing coupling 7 and pipes 9 into inner distribution conduit 6; vertical pipes 9 are generally of the same size as conduits 6. A pair of apertures 6*a*, disposed 180° with respect to each other, discharge the quench stream onto an imperforate portion of outer distribution conduit 5 which contains four apertues 5*a*, each of which is disposed 30° with respect to the vertical axis.

The spacial relationships of distribution conduits 5 and 6, as well as apertures 5*a* and 6*a*, are illustrated in Figs. 3 and 4, enlarged for clarity. Also shown in these views is a stabilizing disc 10 and, in the second alone, a perforated screen member 11 which surrounds outer distribution conduit 5. The jet action of the quench fluid discharging through apertures 6*a* effectively pumps the reactant stream through apertures 5*a*, and intimately admixes therewith by virtue of discharging against the imperforate portion of outer conduit 5. The apertures 11*a* in perforated screen member 11 are sized to inhibit the passage of catalyst particles therethrough.

Fig. 5 shows the positioning of the stabilizing discs, or washers, 10 on the inner distribution conduit 6. As shown, adjacent pairs thereof effectively separate apertures 6*a* from each other. Fig. 6 illustrates more clearly the individual internal chambers 13 which are formed by the pairs of stabilizing discs 10. Stabilizing disc 10*a* is installed as shown in order to divert the fluid quench stream in conduit 9 such that the same traverses the entire length of inner distribution conduit 6. Between pairs of stabilizing discs 10 are the stagnant areas 12.

CLAIMS

1. A fluid distribution device for use in a catalytic reaction chamber containing a fixed bed of catalyst particles, to distribute fluid within the catalyst bed, which device comprises, in cooperative relationship:

(a) a fluid inlet conduit;

(b) a first plurality of spaced-apart, perforated fluid distribution conduits in open communication with the fluid inlet conduit and disposed in a plane perpendicular to the vertical plane containing the axis of the fluid inlet conduit; and,

(c) a second plurality of perforated fluid distribution conduits, having a nominal diameter greater than the first distribution conduits, one each of which is coaxially and concentrically disposed around each of the first distribution conduits.

2. A fluid distribution device as claimed in claim 1 wherein the first and second fluid distribution conduits are disposed below the fluid inlet conduit.

3. A fluid distribution device as claimed in claim 1 or 2 wherein the perforations in the second plurality of distribution conduits have a greater nominal diameter than the perforations in the first plurality of distribution conduits.

4. A fluid distribution device as claimed in any of claims 1 to 3 wherein annular-form, spaced-apart stabilizing discs having a major diameter substantially the same as the internal diameter of the second distribution conduits surround the first distribution conduits and are disposed substantially perpendicular to the longitudinal axis thereof.

5. A fluid distribution device as claimed in claim 4 wherein adjacent pairs of the stabilizing discs form individual internal chambers, containing both first and second distribution conduit perforations, along the length of the first and second distribution conduits.

6. A fluid distribution device as claimed in any of claims 1 to 5 wherein each of the second distribution conduits is encased in a cylindrical, perforated screen member.

7. A fluid distribution device as claimed in any of claims 1 to 6 wherein the perforations in the second distribution conduits are inwardly chamfered.

8. A fluid distribution device as claimed in any of claims 1 to 7 wherein the perforations in the first distribution conduits are disposed to discharge against an imperforate portion of the second distribution conduits.

9. A fluid distribution device as claimed in claim 8 wherein the perforations in the first distribution conduits are disposed at an angle of 90° with respect to the vertical axis and the perforations in the second distribution conduits are disposed at an angle of 30° with respect to the vertical axis.

10. A fluid distribution device as claimed in claim 1 and substantially as hereinbefore described or illustrated with reference to the accompanying drawings.

11. A catalytic reaction chamber designed to contain a fixed bed of catalyst particles and containing a fluid distribution device as claimed in any of claims 1 to 10.

12. A catalytic reaction chamber as claimed in claim 11 wherein the fluid distribution device occupies from 60% to 90% of the horizontal cross-sectional area of the reaction chamber.

13. An exothermic catalytic reaction wherein one or more fluid reactants are re-

acted in a reaction chamber containing a fixed bed of particles of a catalyst for the reaction and having a fluid distribution device as claimed in any of claims 1 to 10, and a fluid cooling stream is distributed through the catalyst bed by means of the fluid distribution device.

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